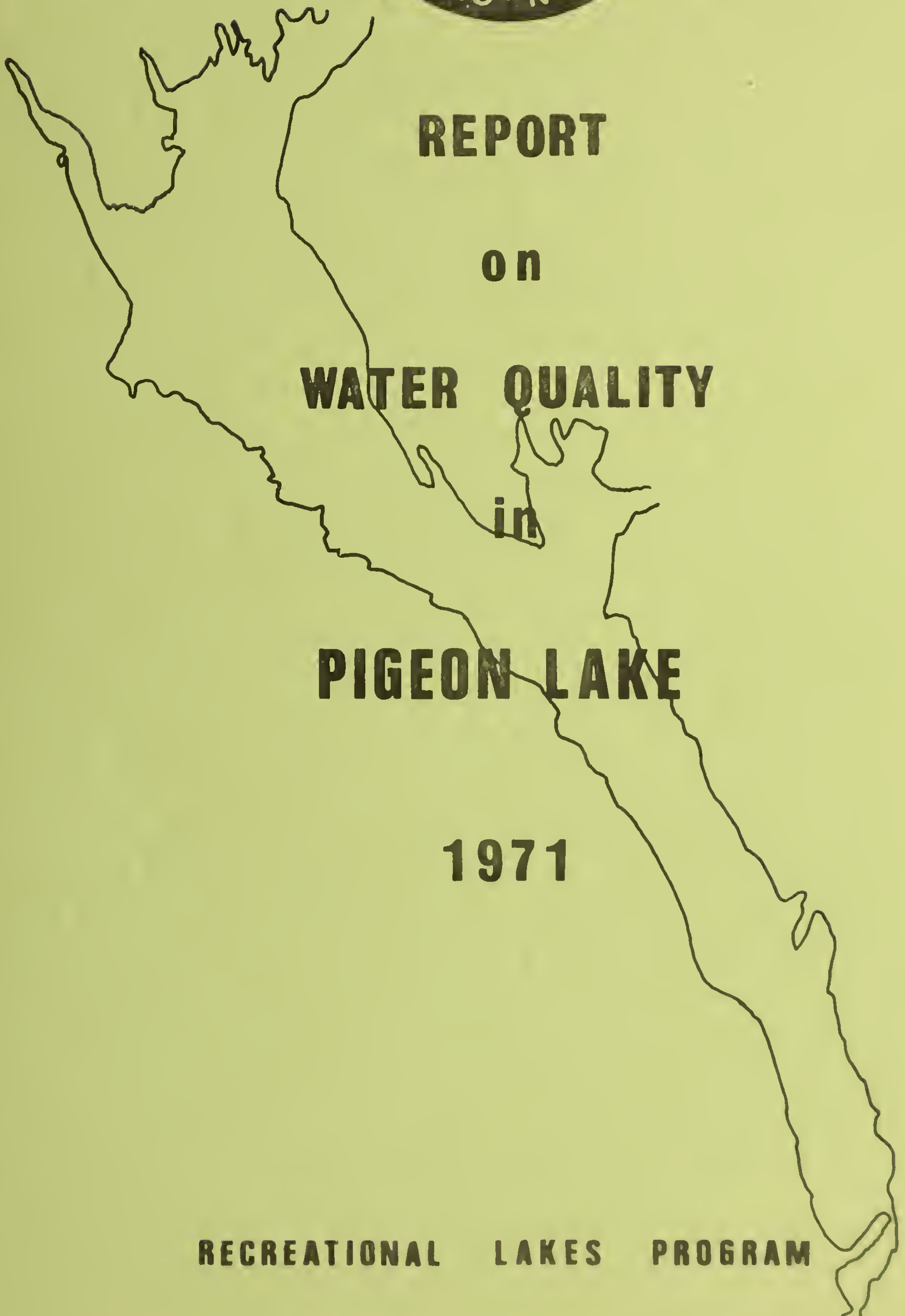
ONTARIO WATER RESOURCES COMMISSION



REPORT

on

WATER QUALITY

in

PIGEON LAKE

1971

RECREATIONAL LAKES PROGRAM

THE

ONTARIO WATER RESOURCES COMMISSION

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SUMMARY

A study to evaluate the status of water quality in Pigeon Lake was carried out during the summer of 1971.

Pigeon Lake lies in two physiographic regions known as the Peterborough Drumlin Field and the Dummer Moraines. The area has a rolling topography and an increasing soil depth from north to south. In general the northern two-thirds of the lake does not have the 1.5 meters (5 feet) of soil cover required by the Ministry of the Environment for the installation of standard subsurface septic tank systems. The prevalent marsh conditions in the remainder of the lake are also prohibitive for cottage development.

Three distinct temperature zones with respect to depth characterized stations located in the deeper sections of Pigeon Lake during June and July. During this period, low deep-water dissolved oxygen concentrations and high carbon dioxide levels resulting from decomposition of organic matter were observed. During August and September, uniform temperature and dissolved oxygen regimes were apparent throughout the lake.

The enriched nature of the lake's drainage basin was revealed by relatively high mean values for total Kjeldahl nitrogen (0.54 mg/l) and total phosphorus (0.028 mg/l) - two nutrients critical to aquatic plant and algae growth.

Algal levels as measured by chlorophyll a concentrations were high during August and September. Such high densities severely reduce water quality for water-oriented recreational activities such as swimming, boating and water-skiing and diminish the aesthetic quality of the lake. In view of the high nutrient and chlorophyll concentrations, every effort should be made to prevent

any direct flow or leachate from domestic waste disposal systems or other potential sources of pollution from gaining access to the lake.

Generally, Pigeon Lake was well within the OWRC bacteriological recreational use criteria during all three surveys. In June, Station 2, with 2,840 TC/100 ml and 42 FS/100 ml and Station 32 with 144 FC/100 ml exceeded this criteria. In July, Stations 1 and 2 exceeded the FS criterion.

The area within the influence of the Town of Bobcaygeon and the area surrounding Station 2 showed consistently high bacterial levels during all three surveys. Stations 18, 19 and 20 and 56 had high bacterial levels during June and July.

The Ontario Water Resources Commission issued a water pollution report of the Village of Bobcaygeon in 1966. This report concluded that contaminated discharges were gaining access to the Otonabee River and that a municipal sewage works should be installed. Subsequently, the village has been investigating methods to install a sewage works under the provincial method of financing.

A cottage pollution control survey of Pigeon Lake was completed in 1972 by the Private Waste and Water Management Branch of the Ministry of the Environment. Any cottages found to be polluting the lake would be required to correct their defective waste disposal systems.

INTRODUCTION

Maintenance of good water quality in recreational lakes in the Province of Ontario is of vital concern to the Ontario Ministry of the Environment and other governmental agencies involved in tourism and the control and management of shoreline development of cottages and resorts. In 1970 an interdepartmental program was established to survey a number of recreational lakes in order to detect and correct sources of water pollution and ensure that our lakes would be well managed to protect water quality. The Ontario Department of Health, whose jurisdiction in this program was transferred to the Ministry of the Environment in December 1971, would carry out on-shore inspection and correction of faulty private waste disposal systems, whereas the Ontario Water Resources Commission (now within the Ministry of the Environment) would evaluate the existing water quality of the respective lakes. A record of the present status of the private waste disposal systems and the lake water quality would also be documented for comparative use in any future studies.

Recreational lakes are subjected to two major types of water quality impairment; bacteriological contamination and excessive growths of algae and aquatic weeds (eutrophication). The two problems may result from a common source of wastes but the consequences of each are quite different. Bacteriological contamination by raw or inadequately treated sewage poses an immediate public health hazard if the water is used for bathing. In order for this to occur, raw wastes or inadequately treated wastes must gain entry to the lake although it may not be obvious upon visual inspection of the site. It must be noted that no surface water is considered safe for human consumption without prior treatment including disinfection. The

algae and weed growths impair aesthetic values and recreational use of a lake but seldom pose a health hazard. There are nutrient sources other than sewage wastes which do not create serious bacterial hazards but do support nuisance plant growths such as agricultural fertilizer losses and normal nutrient runoff from forest and field.

In order to carry out its responsibility of evaluating the status of water quality in recreational lakes, the Ontario Water Resources Commission undertook a study on Pigeon Lake in the summer of 1971. This study included the assessment of the lake with stress being placed on the bacteriological and nutrient enrichment problems.

Physical, chemical and biological surveys were conducted 4 times during 1971. Three bacteriological surveys were conducted: a spring survey from June 18 to 22, a mid-summer survey from July 23 to August 2 and a fall survey from September 10 to 14 inclusive. Sampling each day for a minimum of five days is mandatory for a reliable assessment of bacteriological conditions.

In addition to the results obtained from these studies, information from other governmental agencies has been incorporated in this report which is the Ontario Water Resources Commission's contribution to the Interdepartmental Task Force Report which will deal with the overall cottage pollution program in Ontario.

The "Kawartha Lakes Water Management Study" was also initiated in 1971 to examine the complex problems of eutrophication which exist in the Kawartha Lakes. The broad objective of this study is to develop a water management plan to protect and develop the recreational potential of the watershed. Included in this study are programs to evaluate the trophic status of the lakes, the sources of nutrients to the lakes, the nutrient cycling system within the lakes and the specific effects on the water environment of various wastewater inputs. An experiment is also planned to evaluate weed cropping, both as a method of enhancing the recreational use of a lake and of providing a nutrient drain that could significantly reduce the quantity of nutrients available for plant growth in the future. Along with this experiment, effects of weed cropping on the sports fishery of a lake is being evaluated by fisheries biologists of the Department of Lands and Forests (now within the Ministry of Natural Resources). The study is expected to continue for at least three years and some data from the first year is included in this report.

A joint federal-provincial study committee (CORTS) has recently released a report entitled "The Rideau-Trent-Severn - Yesterday Today Tomorrow" which considers optimum recreational development of the Rideau-Trent-Severn waterway corridor which includes part of the Kawartha Lakes. Water and other environmental pollution problems received the highest priority in the list of recommendations in this report which was started in 1967. Other recommendations were made dealing with the use of open space, historical preservation

and interpretation, public use areas and other topics designed to develop the corridor as a recreation resource. Many of the recommendations of this report have already been implemented by various federal and provincial agencies such as nutrient budget studies and correction of industrial waste discharges to the waterway.

Geography and Topography

Pigeon Lake is approximately 20 kilometers (12 miles) northwest of Peterborough and is located in the townships of Verulam and Emily in the County of Victoria and the Townships of Ennismore and Harvey in the County of Peterborough.

The lake lies in two physiographic regions which are the Peterborough Drumlin Field and the Dummer Moraines. The dividing line of the two regions runs east to west across the lake between Boyd Island and Gannon Narrows. South of this line lies the Peterborough Drumlin Field which is characterized by rolling terrain and Trenton limestone bedrock. The shore south of Gannon Narrows to Fee Landing has a mixture of soils. Much of this shoreline lies in marsh conditions having saturated mineral soils and very poor drainage. The marsh area is backed by two main soil series. The dominant series is the Otonabee, a moderately stony, loam soil with good drainage and a moderate to steep sloping topography. The second soil series is the Brighton, a stone-free sandy loam soil with good drainage, and gently rolling topography. North from Gannon Narrows the bedrock is Black River limestone which gives way to Precambrian bedrock along the north shore. The Black River limestone is overlain with shallow till which has formed into the Dummer soil series. This soil is a stony calcareous, gravelly-loam till characterized by good drainage. The north shore is generally Precambrian outcropping with very little soil cover.

In general, the soil depth increases from the north end of the lake to the south. In most instances the northern two-thirds of the lake has a soil cover less than the 1.5 meters (5 feet) required by the Department of the Environment for the installation of septic tank systems.

Pigeon Lake has a water surface area of 47 square kilometers (11,500 acres), a shoreline length of 123 kilometers (77 miles) and a maximum depth of 12 meters (40 feet).

Climate Range

The region of the Kawartha Lakes has colder winters and later springs than those regions lying closer to the moderating effects of the Great Lakes. The mean annual temperature is 6°C (43°F) while the winter and summer mean temperatures are -8°C (18°F) and 19°C (66°F) respectively. The annual precipitation ranges from 67 centimeters (26 inches) to 86 centimeters (40 inches) of which 200 centimeters (80 inches) is snow. According to meteorological reports, the area enjoys about 240 days with no measurable precipitation. The summer climate is conducive to most recreational activities and the winter with its abundance of snow provides for participation in most winter sports.

Water Movement

The Pigeon Lake drainage basin, includes the Pigeon River, Nogies Creek and Squaw River drainage basins and is approximately 1,060 square kilometers (410 square miles). There are five permanent inlets to the lake: the Pigeon River, the Bobcaygeon River which is controlled by locks and dams regulated by the Federal

Ministry of Transport, Nogies Creek, Volturno Creek and the Squaw River which enters the lake via Little Bald Lake. The only lake outlet is at Gannon Narrows which empties into Buckhorn Lake.

Shoreline Development

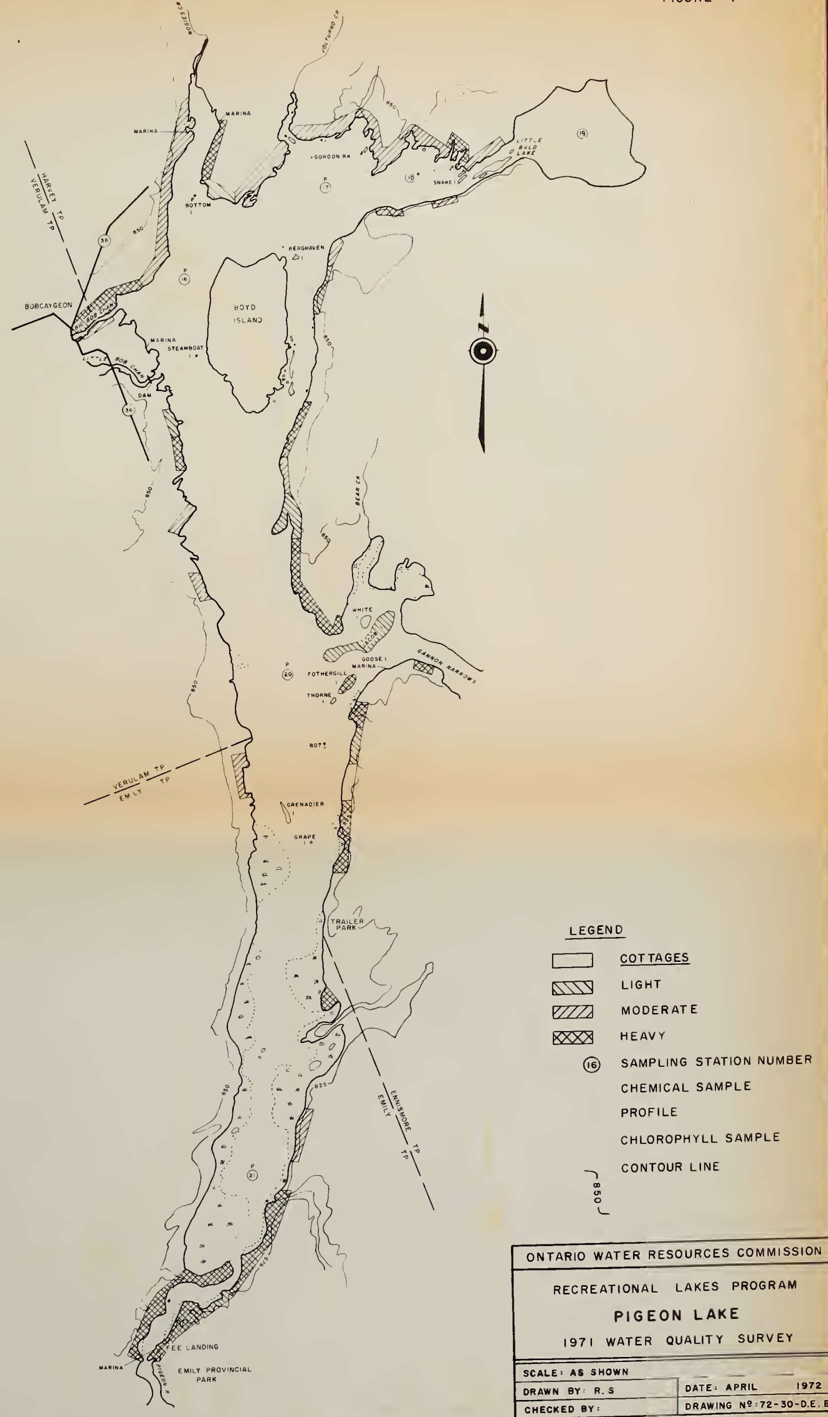
Pigeon Lake is located near Peterborough and the densely populated urban areas of Lake Ontario. This has led to an early and heavy shoreline development. The appended map (Figure 1) shows the relative density and location of the approximate 2,000 cottages. The shoreline north of Grenadier Island is generally well-developed while the shallow water and profuse weed growth on the south shoreline restricts development to localized areas. Most of the shoreline in the southern half of the lake has been cleared for farming.

Water Usage

Although there are a few private wells for the permanent homes on the shore, most cottagers use the lake water as their source of domestic water supply. The lake is mainly used for recreational purposes such as boating, swimming and angling. According to information available from the Department of Lands and Forests the common fish are maskinonge, smallmouth and largemouth bass, walleye, catfish, carp, pumpkinseed, yellow perch, rock bass and white suckers.

Pigeon Lake is part of the Trent Canal System and according to the Department of Tourism and Information, 18,516 boats used the system in 1969. Boaters spent an estimated $8.6 million and an additional $3.6 million was spent by the Federal Department of Transport for operation, maintenance and capital expenditure. Thus, $12.2 million

FIGURE 1



ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

PIGEON LAKE

1971 WATER QUALITY SURVEY

SCALE: AS SHOWN	
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was injected into the economy of those areas adjacent to the Trent Canal in 1969.

Waste and Refuse Disposal

Previous pollution surveys of the Village of Omemee have indicated the presence of contamination in storm sewer and drainage courses to the Pigeon River. A provincial project to provide a municipal sewage works has now reached the final design stage.

The Village of Bobcaygeon, population 1,300, lies on the Bobcaygeon River adjacent to Pigeon Lake. Previous pollution surveys have indicated that wastes are gaining access to the river at several locations. Problems with the operation of private septic tank systems are to be expected because of prevalent shallow soil cover overlying limestone bedrock.

There does not appear to be any pollution from the operation of existing municipal solid waste disposal sites.

FIELD AND LABORATORY METHODS

Physical, Chemical and Biological Field Methods

In selecting the physical, chemical and biological sampling sites on Pigeon Lake an endeavour was made to choose the deepest locations. As well, a sufficient number of additional stations were sampled to represent adequately the entire lake (Figure 1).

Temperature profiles were determined at each station using a telethermometer. Dissolved oxygen levels were measured using the alkalide azide modification of the Winkler method (Standard Methods 13th Edition). Additionally, samples for pH, total alkalinity and free carbon dioxide were collected 1m below the surface and 1m above bottom using a Van Dorn water sampler. The total alkalinity and free carbon dioxide concentrations were determined titrimetrically at the mobile laboratory located at Trent University, Peterborough.

At each station, two 32-ounce samples were collected using a composite sampler lowered through the euphotic zone (2X Secchi disc) or lowered to 1m above bottom whichever was less. One sample, for chlorophyll analysis, was immediately preserved with 10-15 drops of a 2% $MgCO_3$ suspension. The second was divided into two sub-samples; the first sub-sample was frozen for phosphorus and nitrogen analyses, and the second was refrigerated and subsequently analyzed for iron and hardness. In addition when the euphotic zone did not extend to the bottom, samples were collected from 1m above the sediment using a Van Dorn sampler and submitted for phosphorus, nitrogen, iron and hardness.

Physical, Chemical and Biological Laboratory Methods

All analyses were carried out using routine OWRC methods based on Standard Methods 13th Edition.

Iron was measured after the sample had been digested with acid to dissolve all forms of iron present.

Kjeldahl nitrogen and total phosphorus were determined after the sample was digested with acid an oxidizing agent to destroy organic matter.

For chlorophyll determinations, 1 liter samples were filtered through a 1.2 μ membrane filter which was then extracted with 90% acetone for 24 hours. Absorbance of the extract was determined at wavelengths from 600 to 750 mμ using a Unicam SP1800 ultra violet spectrophotometer. The concentrations of chlorophyll _a_ were calculated using the equation given by Richards and Thompson (1952).

Bacteriological Field and Laboratory Methods

Five-day intensive bacteriological surveys were completed in June and September, and one eleven-day survey was completed in July on Pigeon Lake. In June and July, 66 samples were taken daily, including four depths samples at Stations 13D, 25D, 36D and 52D. In September, 50 samples were taken daily, including depth samples at Stations 13D and 52D.

Stations 3, 5, 8, 9, 10, 12, 24, 25, 25D, 31, 36, 36D, 37, 44, 49 and 51 were not sampled in September.

Surface samples were collected at a depth one meter below the surface using sterile, autoclavable, polycarbonate 250 ml bottles. Depth samples were collected one meter above the bottom using a modified "piggy back" sampler and sterile 237 ml evacuated rubber air syringes.

All samples were stored on ice and delivered to the mobile laboratory within two to six hours and analyzed for total coliforms, fecal coliforms and fecal streptococcus using the membrane filtration (MF) technique (Standard Methods 13th Edition) except that m-Endo Agar LES (Difco) was used for total coliform and MacConkey membrane broth (Oxoid) was used for fecal coliform determinations. The total coliforms (TC), fecal coliforms (FC) and fecal streptococcus (FS) were used as "indicators" of fecal pollution. The "indicators" are normal flora of the large intestine, and are present in large numbers in the feces of man and animals. When water is polluted with fecal

material, there is a potential danger that pathogens or disease causing micro-organisms may also be present.

The coliform group is defined, according to Standard Methods 13th Edition, as "all of the aerobic and facultative anaerobic, gram-negative, non-sporeforming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C" and, or "all organisms which produce a colony with a golden-green metallic sheen within 24 hours of incubation" using the MF technique. This definition includes, in addition to the intestinal forms of the *Escherichia coli* group, closely related bacteria of the genera *Citrobacter* and *Enterobacter*. The *Enterobacter* - *Citrobacter* groups are common in soil, but are also recovered in feces in small numbers and their presence in water may indicate soil runoff or, more important, less recent fecal pollution since these organisms tend to survive longer in water than do members of the *Escherichia* group, and even to multiply when suitable environmental conditions exist. A more specific test for coliforms of intestinal origin is the fecal coliform test, with incubation of the organisms at 44.5°C. Though by no means completely selective for *Escherichia coli*, this test has proved useful as an indicator of recent fecal pollution.

Fecal streptococci (or enterococci) are also valuable indicators of recent fecal pollution. These organisms are large, ovoid gram-positive bacteria, occurring in chains. They are normal inhabitants of the large intestine of man and animals, and they generally do not multiply outside the body. In waters polluted with fecal material, fecal streptococci

are usually found along with coliform bacteria, but in smaller numbers, although in some waters they may be found alone. Their presence, along with coliforms, indicates that at least a portion of the coliforms in the sample are of fecal origin.

Bacteriological Statistical Methods

Fluctuations in bacterial concentrations due to changing environmental conditions require that a great number of samples be taken to arrive at a mean value which is representative of a specific sample location or sampling area. The most appropriate mean for bacterial levels and this type of data is the geometric mean. The vast quantities of bacteriological data generated from these samples necessitated the development of additional statistical methods to summarize the mean results into a more concise presentation. The statistical methods used are based on the analysis of variance. The stations on a lake can be grouped, by this method, into areas or groups of stations within the same statistical bacterial level, without the bias normally associated with manual interpretation.

The analysis of variance is particularly effective where bacterial concentrations vary slightly throughout the lake. Areas or stations with only slight differences in bacterial concentration can be isolated. Areas or stations with statistically higher bacterial numbers reliably indicate an input.

The results from all the analyses were organized as replicates representing the stations during the survey period. All data were transformed to logarithms (base 10) and all further analyses were done using these

transformed data. A geometric mean (the antilogarithm of the average of the logarithm) was calculated on each station and for each parameter. The validity of the analysis of variance program (ANOVA-CRE; Burger, 1972), was based on the assumptions that the variances of all the stations were similar (Bartlett's test of Homogeneity) and that the data were normally distributed.

Both these assumptions were checked on Pigeon Lake. The Bartlett's test was found to be non-significant and the data followed a normal distribution, hence the analysis of variance (F-test; Sokal, 1969) was calculated on all the stations. Pigeon Lake, during June and July, was divided into two sections, between Falls Point and Sandy Point, to accommodate the ANOVA-CRE program which allows a treatment of a maximum of fifty stations.

If the F was significant, then the multiple-t test was used to help determine the stations which should be deleted from the overall group to yield a homogeneous group of stations. The withdrawn stations were regrouped with respect to geographic proximity and similar means. The calculations on all groups were repeated using the analysis of variance program until each discrete group was homogeneous. The homogeneous groups that were geographically isolated were compared by means of the Student-t test (using the log GM and S.E.) which indicated the statistical difference between these groups. The Student-t test was also used to compare the grouped bacteriological data from the June, July and September surveys.

DISCUSSION OF RESULTS

Temperature and Dissolved Oxygen

Six stations were established on Pigeon Lake for measuring temperature and dissolved oxygen profiles (P-16, P-17, P-18, P-19, P-20 and P-21; Figure 1).

In June, a well-defined thermocline or zone of rapid temperature decline was apparent between 5 and 7m at Stations P-16, P-17 (Figure 2a) and P-19. However, Stations P-18, P-20 and P-21 were located in shallower waters where thermal stratification did not develop owing to complete mixing from wind action. Oxygen saturations in the upper strata ranged from 90 to 95% mg/l throughout the lake. Deep-water oxygen saturations were only 10 to 20% at Stations P-16, P-17 and P-19. These low oxygen levels resulted from bacterial oxidation of organic matter, biological respiration and chemical oxidation.

In July, the thermocline was located between 8.5 and 10.0m of depth at Stations P-1, P-2 and P-4, whereas at the remaining sampling sites temperatures were uniform with depth. Oxygen conditions were similar to those recorded in June for all stations.

In August, only minor temperature differences were apparent between surface and bottom waters (Figure 2c) at the six sampling locations. Anoxic (oxygen-poor) or near-anoxic conditions were detected 1m above bottom at Stations P-17 and P-19.

In September, homogeneous oxygen conditions generally prevaled throughout the lake and water temperatures were considerably reduced in comparison to the early surveys indicating autumnal cooling (Figure 2d). Occasional surface

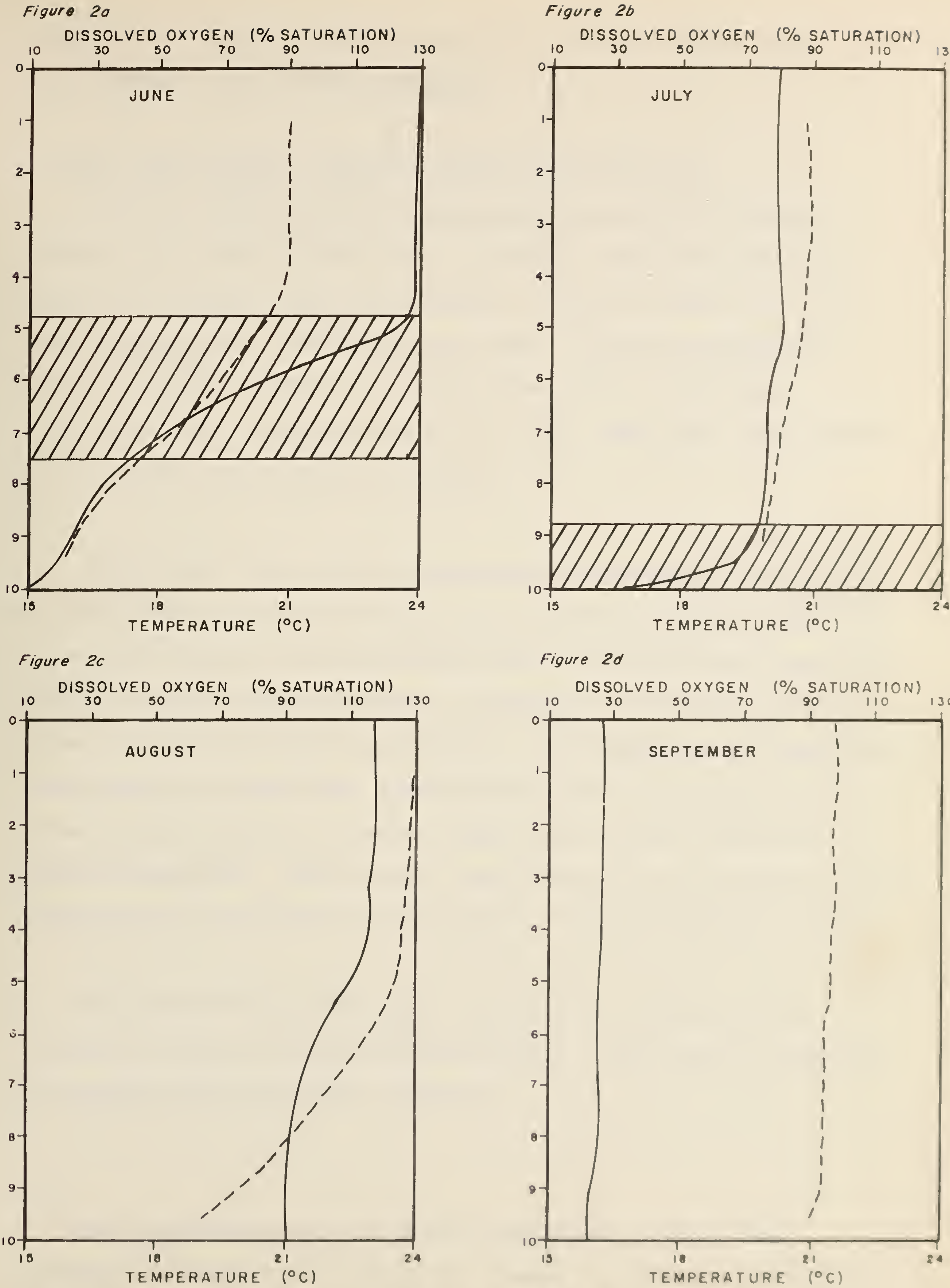


FIGURE 2: DISSOLVED OXYGEN AND TEMPERATURE PROFILES AT P-17 IN PIGEON LAKE. THE SHADED AREA REPRESENTS THE THERMOCLINE.

saturations of dissolved oxygen as high as 125% owing to the development of an intensive bloom of blue-green algae.

pH, Free Carbon Dioxide, Alkalinity, Hardness and Conductivity

Generally, relatively low pH readings were recorded at the deep-water stations (i.e., P-16, P-17 and P-19); in contrast, values were consistently above 8.0 at stations located in the shallow, productive southern end of the lake (P-20 and P-21). Additionally, as a result of greater photosynehetic activity by algae, pH values were usually higher in the surface waters (6.8 - 8.5) than in the deeper strata (6.4 - 8.3). Lakes having a pH in excess of 8.3 may cause eye irritation to swimmers.

Surface water carbon dioxide concentrations were relatively low throughout the year (Table 1). At Stations P-16, P-17, P-18 and P-19 concentrations were substantially higher in the deeper waters than in the surface strata, especially during the months of July and August. For example, at Station P-19 on August 19 at 1m of depth and 1m above the sediments, values of 3.3 and 19.5 respectively were measured. The high carbon dioxide levels (as well as the depressed pH values mentioned above) in the deeper strata can be related to conditions of organic decomposition. During August, concentrations of zero or near-zero in the surface waters coincided with the peak period in algal photosynthetic activity.

Mean concentrations for hardness, alkalinity and conductivity were, 97 mg/l, 77.2 mg/l and 200 μmhos/cm^3 respectively. These values are indicative of moderately hard water quality conditions.

Iron

Iron concentrations were low in the surface waters of Pigeon Lake throughout the sampling period (Table 2). However, at Stations P-16, P-17 and P-19 where deep-water oxygen depletions developed, iron concentrations as high

as 0.50 mg/l (P-16) and 2.90 mg/l (P-19) were recorded, suggesting the presence of a significant iron-phosphorus re-cycling mechanism. A number of authors (including Mortimer 1941 and 1971 and Hutchinson 1967) indicate that this mechanism is important in augmenting algal production in a lake.

Total Kjeldahl Nitrogen and Total Phosphorus

Relatively high mean values for nitrogen (0.5 mg/l) and phosphorus (0.028 mg/l) for Pigeon Lake reflect the enriched nature of the lake. Hypolimnetic or deep-water nutrient levels were slightly elevated under anoxic conditions, suggesting that re-cycling of nitrogen and phosphorus from the sediments was occurring. Generally, troublesome levels of algae appear when total phosphorus concentrations exceed 0.020 mg/l. The mean value for total phosphorus (0.028 mg/l) which exceeded this limit was consistent with the observed excessive aquatic plant and algal growths. As the lake is naturally enriched, further inputs from municipal drainage, agricultural runoff, inflowing streams and from malfunctioning or improperly installed domestic waste disposal systems will serve to accelerate the process of eutrophication.

Chlorophyll a

Algal levels as reflected by chlorophyll a were moderately high during the June and July surveys as values ranged from 2.3 to 7.7 µg/l. During August and September, chlorophyll a was as high as 26.0 µg/l corresponding to a wide-spread extensive bloom of blue-green algae. Such high algal production severely reduces water quality for recreational activities such as swimming and water skiing and diminishes the aesthetic quality of the lake.

Water clarity, which is one of the more important parameters used in defining water quality, can be measured using a Secchi disc. Figure 3 presents

FIGURE 3

CHLOROPHYLL a - SECCHI DISC RELATIONSHIP

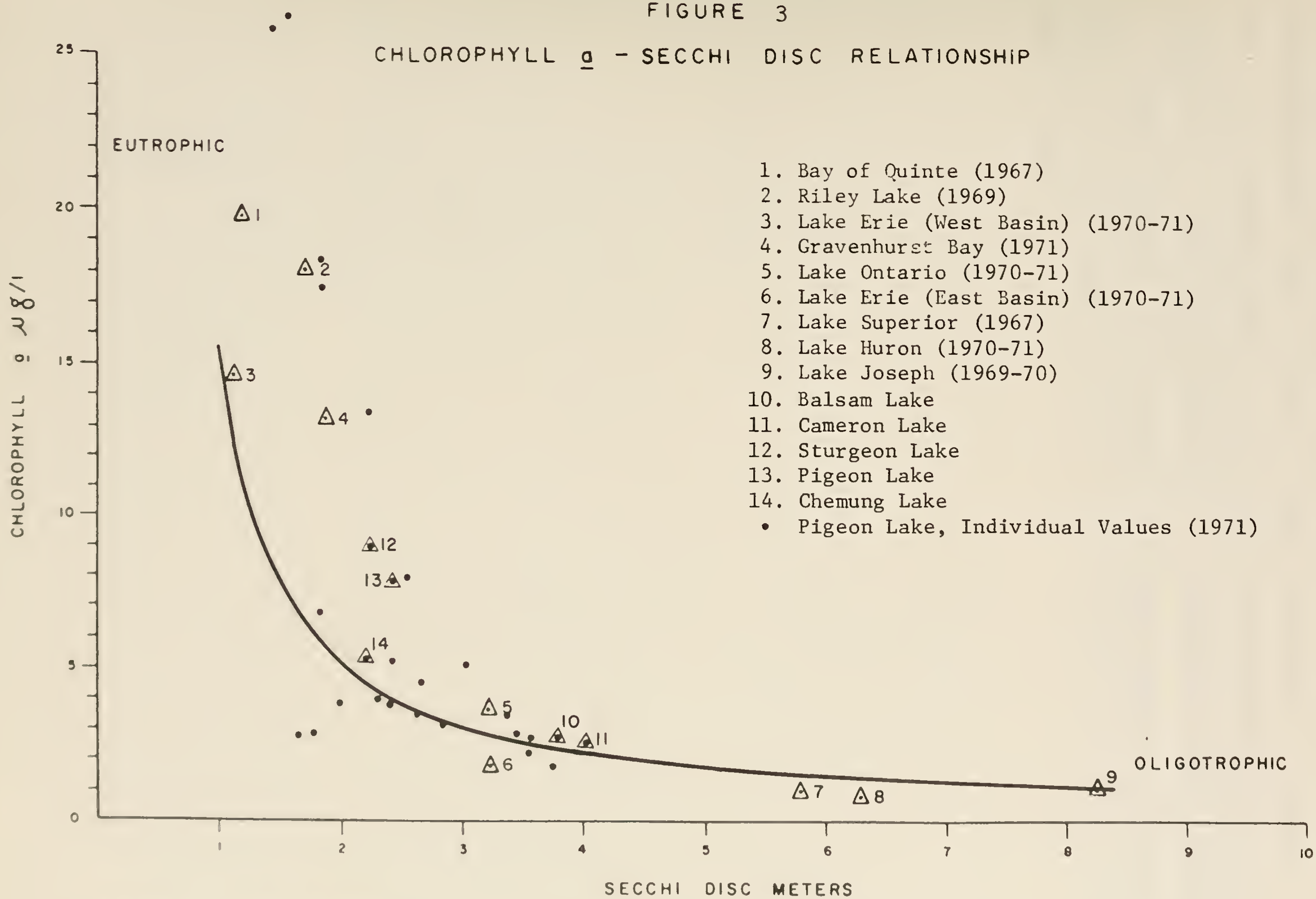


Figure 3: The relationship between chlorophyll a and Secchi disc as determined from the recreational lakes surveyed in 1971 as well as the individual and mean values of chlorophyll a and Secchi disc for Pigeon Lake. The values for the Great Lakes were added for comparative purposes.

a chlorophyll a - Secchi disc relationship for a number of surface waters and clarifies the "trophic status" of Pigeon Lake relative to numerous other well-known recreational lakes in the province (see Brown 1972 for derivation of chlorophyll a - Secchi disc relationship). The enriched status of Pigeon Lake is indicated (Figure 3) by its proximity to values computed for the Bay of Quinte, the Western Basin of Lake Erie and Gravenhurst Bay - three eutrophic bodies of water.

Bacteriology

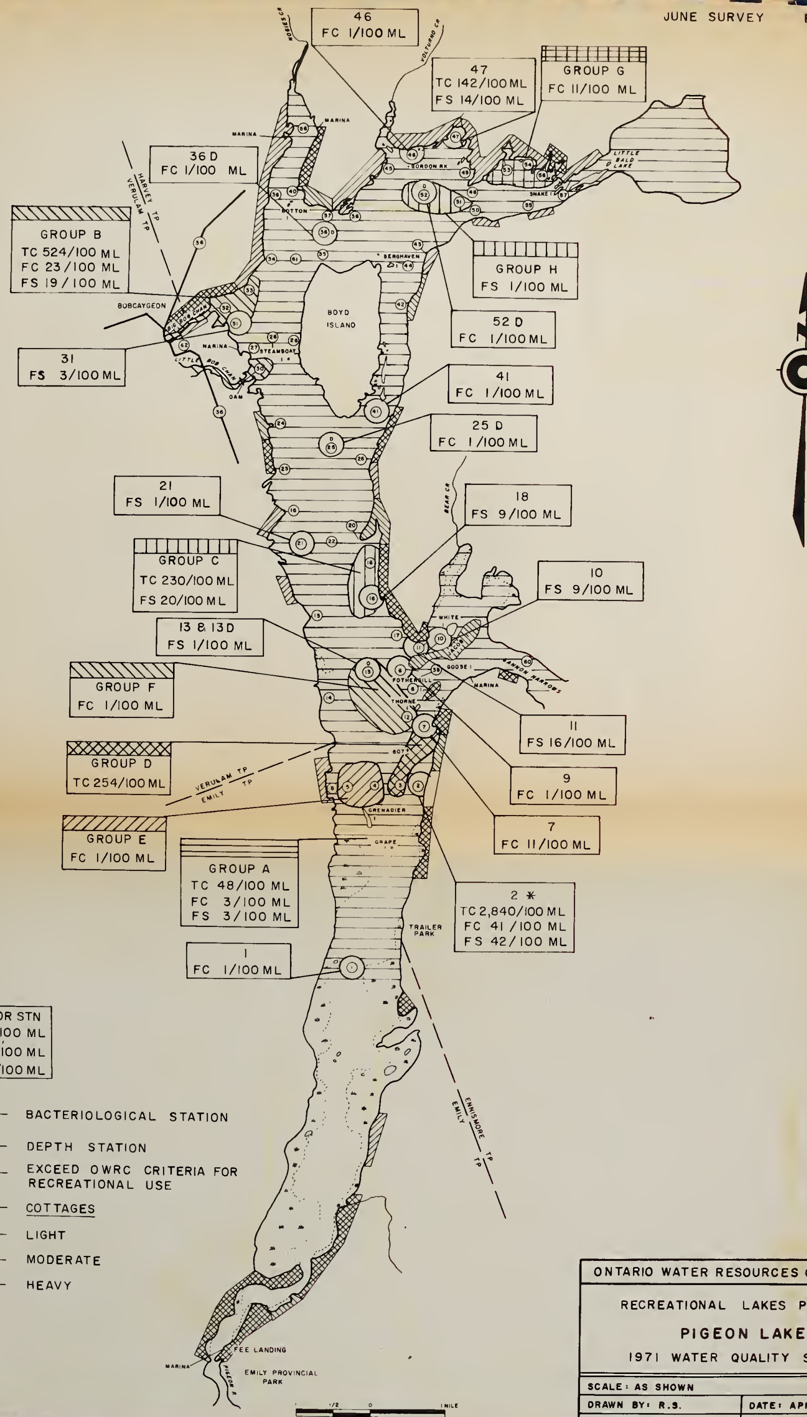
Generally, Pigeon Lake was within the criteria for total body contact recreational use during all three surveys. However, certain well-defined areas on the lake had consistently higher bacterial levels and in some cases exceeded the OWRC criteria.

In June (Figure 4), the majority of stations, Group A, had low bacterial means of 48 TC/100 ml, 3 FC/100 ml and 3 FS/100 ml (Tables 3, 4, 5). Weekend recreational activity followed by the June 21 rainfall (0.95 inches, recorded at the Peterborough Meteorological Station) resulted in increased bacterial levels particularly near the heavily populated areas where the recreational use criteria was exceeded

Station 2 with 2,840 TC/100 ml, 41 FC/100 ml and 42 FS/100 ml was in a shallow, weedy area bordered by a shoal 400 feet from shore which may have retained any bacterial input in this area. The FC concentrations at Station 2 exceeded the FC criterion in the first two days of the survey. Group D (Stations 3 and 7) was characterized by a high TC level of 254/100 ml. An additional input with a FC mean of 11/100 ml was detected at Station 7.

Group B, adjacent to the Town of Bobcaygeon indicated a bacterial input with high bacterial levels of 524 TC/100 ml, 23 FC/100 ml and 19 FS/100 ml. Station 32, although statistically similar to Group B had a mean FC level of 144/100 ml which exceeded the OWRC FC criteria for recreational use.

Group C, adjacent to a heavily cottaged and farmed area, on the east shore, had higher means of 230 TC/100 ml and 20 FS/100 ml. Station 18, in Group C, displayed a significantly higher FC mean of 9/100 ml.



LEGEND

GROUP OR STN
TC GM/100 ML
FC GM/100 ML
FS GM/100 ML

(13) — BACTERIOLOGICAL STATION

D — DEPTH STATION

* — EXCEED OWRC CRITERIA FOR RECREATIONAL USE

— COTTAGES

— LIGHT

— MODERATE

— HEAVY

ONTARIO WATER RESOURCES COMMISSION	
RECREATIONAL LAKES PROGRAM **PIGEON LAKE** 1971 WATER QUALITY SURVEY	
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CHECKED BY:	DRAWING Nº: 72-3D-D.E.A

Group G, Stations 53, 54 and 56 in small, densely populated bays showed a higher FC mean of 11/100 ml, while Group H, a mid-lake area had a low FS mean of 1/100 ml.

Station 47, in the heavily cottaged Tait Bay, had bacterial means of 142 TC/100 ml and 14 FS/100 ml which were significantly higher than Group A. Station 11, bordered by a densely cottaged shoreline with high FS counts on the weekend of June 19-20, yielding a high FS mean of 16/100 ml.

In July (Figure 5), Group A had low overall geometric mean bacterial levels of 12 TC/100 ml, 1 FC/100 ml and 3 FS/100 ml (Tables 3, 4 and 5). However, unlike June, no means exceeded the recreational use criteria.

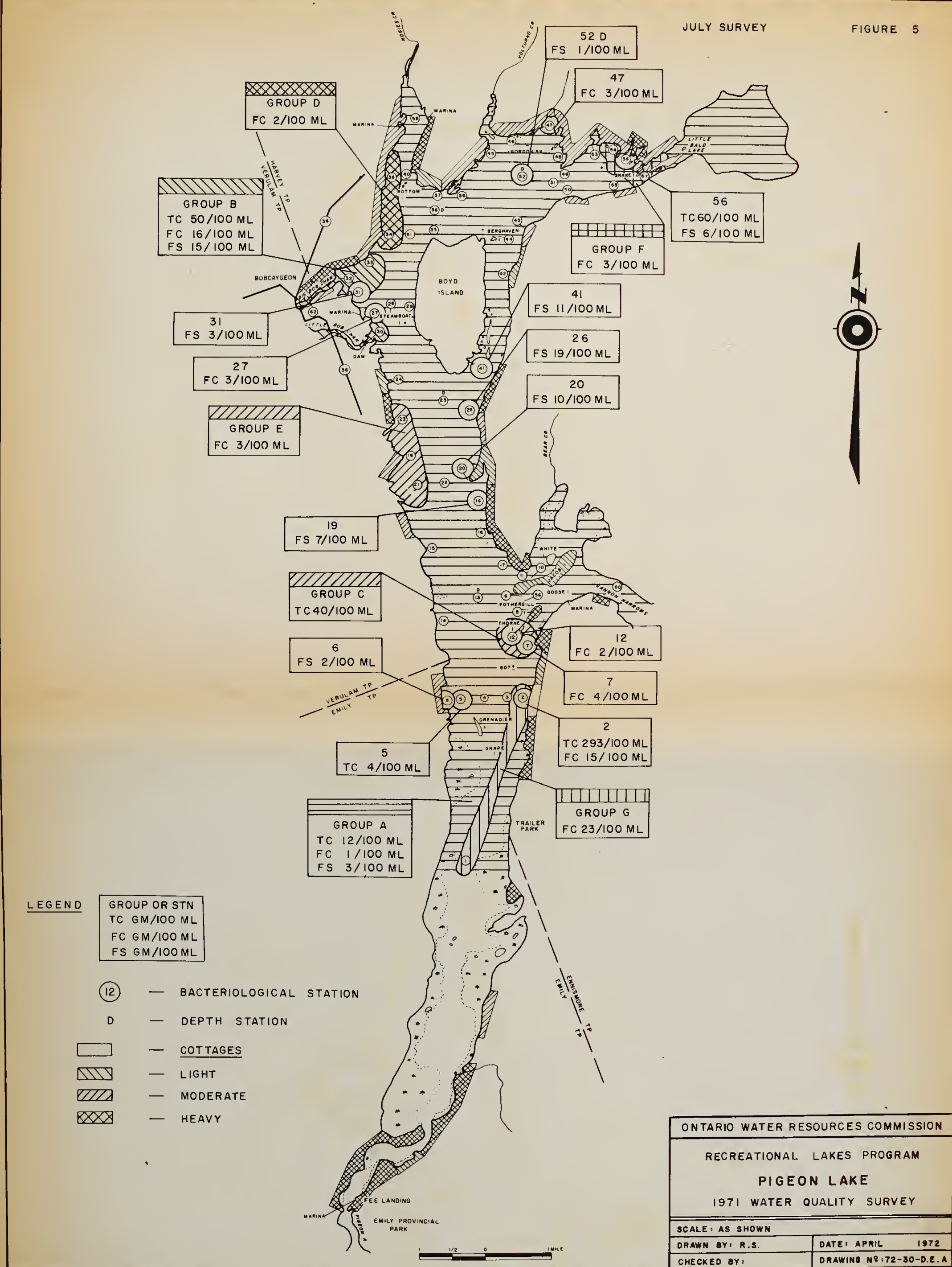
Station 2, bordered by the shoal, again had the highest bacterial levels of 293 TC/100 ml and 15 FC/100 ml. Group G (Stations 1 and 2) displayed an elevated FS mean of 23/100 ml. Group C (Stations 7 and 12) was characterized by TC and FC levels slightly higher than Group A. Group B (Stations 30-33 and 62) yielded a significantly higher bacterial means of 50 TC/100 ml, 16 FC/100 ml and 15 FS/100 ml.

Group F (Stations 54, 56 and 57), adjacent to a heavily cottaged area displayed a slightly higher FC mean of 3/100 ml, while Station 56, within Group F, had higher TC and FS levels of 60/100 ml and 6/100 ml respectively.

Group E, Group D and Stations 27 and 47 displayed slight but statistically higher FC means (Figure 5). Stations 19, 29, 26 and 41 had slightly higher FS means.

JULY SURVEY

FIGURE 5



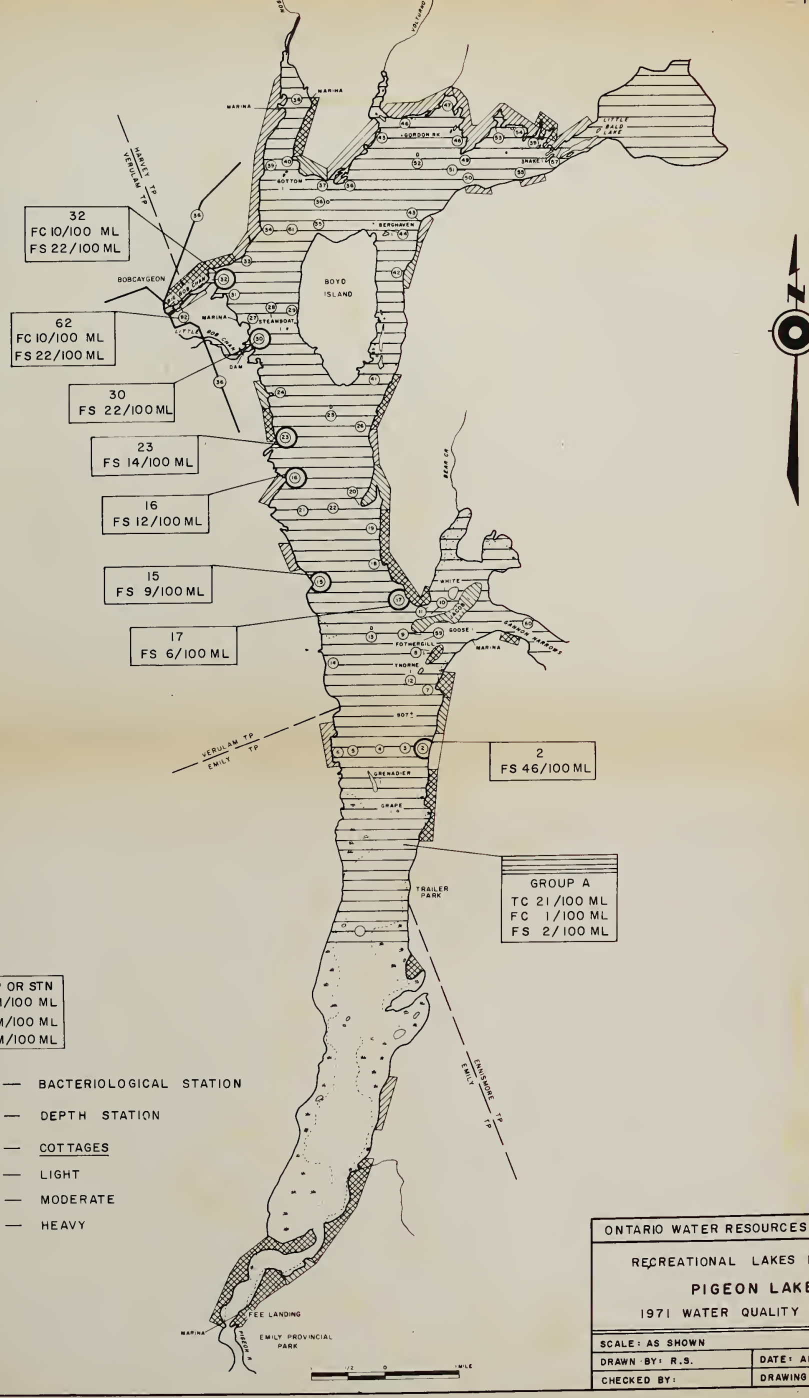
In September (Figure 6), Pigeon Lake generally was homogeneous with 21 TC/100 ml, 1 FC/100 ml and 2 FS/100 ml (Tables 3, 4, 5). However, the antagonistic effect associated with extremely high background counts at all stations may have been responsible for the lower TC levels on the lake. Total coliform levels in excess of the recreational use criteria were recorded on September 13 and 14 at numerous stations along the eastern shoreline and the inflow area of the Bobcaygeon River. These elevated levels were attributed to runoff following 0.53 inches rainfall on September 12 and 0.13 inches rainfall on September 13 recorded at the Peterborough Meteorological Station.

As in the previous surveys, Station 2 with 46 FC/100 ml, and Stations 32 and 62, both with 10 FC/100 ml were significantly higher than Group A. Stations 30, 32 and 62 had an overall FS mean of 22/100 ml exceeding the FS criteria for recreational use. A number of isolated Stations 15, 16, 17 and 23 had statistically higher FS means of 9/100 ml, 12/100 ml, 6/100 ml and 14/100 ml respectively.

In summary, Pigeon Lake displayed little variation in FC and FS levels during the three survey periods. TC means in July were significantly lower than levels in June and September (Table 7). The inflow area influenced by the Town of Bobcaygeon and the area surrounding Station 2 had consistently high bacterial levels in all three surveys. In June and July, the area surrounding Stations 18-20 and Station 56 also showed higher bacterial means.

Although, Pigeon Lake was generally within the OWRC recreational use criteria no surface water is considered potable without prior treatment including disinfection.

SEPTEMBER SURVEY FIGURE 6



LEGEND

GROUP OR STN
TC GM/100 ML
FC GM/100 ML
FS GM/100 ML

(15) — BACTERIOLOGICAL STATION

D — DEPTH STATION

— COTTAGES

— LIGHT

— MODERATE

— HEAVY

ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

PIGEON LAKE

1971 WATER QUALITY SURVEY

SCALE: AS SHOWN	
DRAWN BY: R.S.	DATE: APRIL 1972
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EXPLANATION OF TERMS IN BACTERIOLOGICAL TABLES

F	-	the calculated analysis of variance statistic on F ratio.
df	-	degrees of freedom of the F ratio for "between group" and "within group" variation.
F(5%)	-	the F ratio from a statistics table (Rohlf 1969). If the calculated F is greater than the F(5%), a significant difference (SD) occurred between the groups in the analysis. If the F is less than F(5%), no significant difference (NSD) occurred.
log GM	-	the logarithm (base 10) of the geometric mean.
S.E.	-	the standard error of the log GM where

$$S.E. = \frac{s}{\sqrt{n}} \quad \text{and } s = \text{standard deviation}$$

N	-	the number of values in the mean.
GM	-	the geometric mean of the bacterial level.
t	-	the calculated test of significance or student t-test used to compare stations, groups and a survey.

If t for the number of degrees of freedom shown is greater than the critical t value, a significant difference (SD) occurs.

SD refers to a significant difference at the .05 level but no significant difference at the .01 level.

SD* refers to a significant difference at the .01 level but no significant difference at the .001 level.

SD** refers to a significant difference at the .001 level.

Table 1: Data ranges for temperature, dissolved oxygen, pH, carbon dioxide, total alkalinity and conductivity for Stations P-16, P-17, P-18, P-19, P-20 and P-21 on Pigeon Lake during the summer of 1971.

STATION	SAMPLE DEPTH	TEMPERATURE °C	DISSOLVED OXYGEN % Sat.	pH	CARBON DIOXIDE mg/l +	ALKALINITY mg/l	CONDUCTIVITY umhos/cm3
P-16	1m	16.7-24.1	84-89	7.6 - 7.9	2.4 - 2.7	71.0 - 73.0	145-220
	bottom	15.0-18.2	2-82	6.9 - 7.5	2.5 -13.0	67.0 - 78.2	150-230
P-17	1m	16.3-24.1	88-130	7.6 - 8.6	0.0 - 2.7	72.0 - 75.0	153-225
	bottom	16.0-21.0	24-92	7.0 - 7.6	2.9 -11.4	71.5 -102.5	171-225
P-18	1m	15.4-23.9	83-104	7.5 - 8.2	0.3 - 4.2	74.2 - 77.0	190-230
	bottom	9.3-22.7	4-86	6.8 - 7.5	4.5 -12.2	66.0 - 78.5	146-240
P-19	1m	15.7-23.4	87-110	7.7 - 7.9	2.4 - 3.3	74.0 - 89.8	154-265
	bottom	11.9-18.9	0-106	7.0 - 7.7	2.8 -19.5	50.0 -126.5	178-260
P-20	1m	15.1-21.9	89-106	7.8 - 8.4	0.0 - 2.8	72.0 - 74.5	150-210
	bottom	15.0-21.8	88-102	7.7 - 8.3	0.0 - 2.8	71.5 - 75.0	120-210
P-21	1m	15.0-22.0	89-103	8.0 - 8.2	0.6 - 2.7	75.0-106.0	125-297
	bottom	15.0-22.2					

Table 2: Data ranges for hardness, iron, total Kjeldahl nitrogen, total phosphorus, chlorophyll a and Secchi disc for Stations P-16, P-17, P-18, P-19, P-20 and P-21 on Pigeon Lake during the summer of 1971.

STATION	SAMPLE DEPTH	HARDNESS mg/l	IRON ppm	TOTAL KJELDAHL NITROGEN mg N/l	TOTAL PHOSPHORUS mg P/l	CHLOROPHYLL a ppb	SECCHI DISC m
P-16	composite	84 - 90	.00 - .10	.33 - 1.0	.020 - .078	2.7 - 18.0	1.9 - 3.4
	bottom	82 - 94	.00 - .40	.42 - .86	.022 - .058		
P-17	composite	84 - 90	.00 - .10	.31 - .62	.020 - .032	2.3 - 25.0	1.6 - 3.5
	bottom	86 - 92	.00 - .15	.40 - .90	.024 - .030		
P-18	composite	86 - 90	.00 - .15	.31 - .52	.017 - .030	3.3 - 5.5	2.0 - 2.6
	bottom	82 - 90	.10 - .50	.57 - .66	.036 - .036		
P-19	composite	100 -104	.00 - .05	.34 - .57	.014 - .034	3.2 - 5.0	2.3 - 3.3
	bottom	100 -120	.20 -2.90	.66 - 1.3	.016 - .058		
P-20	composite	88 - 92	.00 - .10	.48 - .66	.024 - .042	4.3 - 26.0	1.7 - 2.6
	bottom	88	.10	.56	.026		
P-21	composite	126 0132	.00 - .05	.63 - .75	.022 - .035	2.8 - 3.7	1.3 - 1.8
	bottom	132					

Table 3

Analysis of Variance - Summary of Groups

Parameter - Total Coliforms/100 ml

SURVEY	JUNE	JULY	SEPTEMBER
Group	All Stations	All Stations	All Stations
F	3.62	2.95	0.693
df	65, 261	65, 645	49, 197
F5%	1.32	1.32	1.44
	SD	SD	NSD
Group	A	A	A
	All stations except 2, 3, 7, 18, 19, 30, 31, 32, 33, 47 & 62	All stations except 2, 5, 7, 12, 30, 31 32, 33, 56 & 62	All stations
F	1.20	0.8197	0.693
df	54, 219	55, 543	49, 197
F5%	1.35	1.39	1.44
	NSD	NSD	NSD
log GM	1.677	1.062	1.372
SE	0.0308	0.0259	0.0605
N	274	599	247
GM	48	12	21
Group	B	B	
	Stations 30, 31, 32, 33 & 62	Stations 30, 31, 32, 33 & 62	
F	1.0987	0.46002	
df	4, 18	4, 50	
F5%	2.926	2.552	
	NSD	NSD	
log GM	2.7195	1.6974	
SE	0.1153	0.1010	
N	23	55	
GM	524	50	

Table 3 - continued

SURVEY	JUNE	JULY	SEPTEMBER
Group	C	C	
	Stations 18 & 19	Stations 7 & 12	
t	0.2984	0.8445	
df	8	17	
t5%	2.306	2.110	
	NSD	NSD	
N	10	19	
GM	230	40	
Group	D		
	Stations 2,3 & 7		
F	4.998		
df	2, 12		
F5%	19.4		
	NSD		
log GM	2.755		
SE	0.1967		
N	15		
GM	568		

Table 4

Analysis of Variance - Summary of Groups

Parameter - Fecal Coliforms/100 ml

SURVEY	JUNE	JULY	SEPTEMBER
Group	All Stations	All Stations	All Stations
F	3.469	12.967	3.615
df	65, 260	65, 650	49, 200
F5%	1.32	1.32	1.440
	SD	SD	SD
Group	A	A	A
	All stations except 1, 2, 4, 5, 7, 9, 12, 13, 13D, 18, 25D, 30 to 33, 36D, 41, 46, 52D, 53, 54, 56, 59 & 62	All stations except 2, 7, 12, 16, 21, 23, 27, 30 to 34, 39, 47, 54, 56, 57 & 62	All stations except 32 & 62
F	0.9060	1.388	1.168
df	41, 168	46, 470	46, 188
F5%	1.39	1.39	1.35
	NSD	NSD	NSD
log GM	.4947	0.0736	0.1210
SE	.0359	0.0103	0.0201
N	210	517	235
GM	3	1	1
Group	B	B	
	Stations 30, 31, 32, 33 & 62	Stations 30, 31, 32, 33 & 62	
F	2.909	3.7037	
df	4, 19	4, 50	
F5%	5.69	5.70	
	NSD	NSD	
log GM	1.365	1.2149	
SE	0.1472	0.0754	
N	24	55	
GM	23	16	

Table 4 - continued

SURVEY	JUNE	JULY	SEPTEMBER
Group	E	D	
	Stations 4 & 5	Stations 34 & 39	
t	0	0.2942	
df	8	20	
t5%	2.306	2.086	
	NSD	NSD	
N	10	22	
GM	1	2	
Group	F	E	
	Stations 12, 13 & 13D	Stations 16, 21 & 23	
F	1.199	0.3430	
df	2, 12	2, 30	
F5%	19.4	19.5	
	NSD	NSD	
log GM	0.0204	0.4477	
SE	.0643	0.0893	
N	15	33	
GM	1	3	
Group	G	F	
	Stations 53, 54 & 56	Stations 54, 56 & 57	
F	0.5169	4.343	
df	2, 12	2, 31	
F5%	19.4	19.5	
	NSD	NSD	
log GM	1.050	0.4978	
SE	0.1797	0.1189	
N	15	34	
GM	11	3	

Table 5

Analysis of Variance - Su-mary of Groups

Parameter - Fecal Streptococcus/100 ml

SURVEY	JUNE	JULY	SEPTEMBER
Group	All Stations	All Stations	All Stations
F	2.8025	2.2887	3.415
df	67, 272	65, 671	48, 196
F5%	1.32	1.32	1.39
	SD	SD	SD
Group	A	A	A
	All stations except 2, 10, 11, 13, 13D, 18, 19, 21, 30, 32, 33, 47, 51, 52, 52D, 54 & 62	All stations except 1, 2, 6, 19, 20, 26, 30, 32, 33, 41, 52D, 56 & 62	All stations except 15, 16, 17, 23, 30, 32 & 62
F	1.3286	1.345	1.131
df	49, 200	52, 548	48, 168
F5%	1.35	1.35	1.58
	NSD	NSD	NSD
log GM	0.5328	0.3902	0.3178
SE	0.0350	0.393	0.0291
N	250	601	210
GM	3	3	2
Group	B	B	B
	Stations 30, 32, 33, & 62	Stations 30, 32, 33 & 62	Stations 30, 32 & 62
F	0.4889	2.049	0.744
df	3, 16	3, 40	2, 12
F5%	5.70	2.843	19.4
	NSD	NSD	NSD
log GM	1.2476	1.185	1.3444
SE	0.1395	0.0802	0.0773
N	20	44	15
GM	19	15	22

Table 5 - continued

SURVEY	JUNE	JULY	SEPTEMBER
Group	C	G	
	Stations 18 & 19	Stations 1 & 2	
t	1.132	0.1902	
df	8	20	
t5%	2.306	2.086	
	NSD	NSD	
N	10	22	
GM	20	23	
Group	H	H	
	Stations 51, 52 & 52D	Stations 19, 20, 26 & 41	
F	0.00	0.4988	
df	2, 12	3, 40	
F5%	3.887		
	NSD	NSD	
log GM	0.00	0.9763	
SE	0.00	0.1677	
N	15	44	
GM	1	10	

GLOSSARY OF TERMS

ALKALINITY	:The alkalinity of a water sample is a measure of its capacity to neutralize acids. This capacity is due to carbonate, bicarbonate and hydrozide ions and is arbitrarily expressed as if all of the neutralizing capacity was due to calcium carbonate alone.
ANOXIC	:Refers to conditions when no oxygen is present.
BACKGROUND COLONIES	:Background colonies are other lake water bacteria capable of growing on the total coliform plate, in spite of the inherent restrictive conditions.
CHLORIDE	:Chloride is simply a measure of the chloride ion concentration and is not a measure of chlorination.
CHLOROPHYLL <u>a</u>	:A green pigment in plants.
CONDUCTIVITY	:Conductivity is a measure of the waters ability to conduct an electric current and is due to the presence of dissolved salts.
DIATOMS	:Unicellular plants found on all continents and in all types of water where light and nutrients are sufficient to support photosynthesis. They are comprised of two siliceous frustules (cell walls) which have an outer valve (epitheca) fitting over the inner valve (hypotheca) like the lid on a box. The siliceous deposits comprising the frustules vary in regular patterns according to the individual species.
EPILIMNION	:Is the thermally uniform layer of a lake lying above the thermocline. Diagram 1.
EUPHOTIC ZONE	:The lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur due to insufficient light penetration.
EUTROPHIC	:Waters containing advanced nutrient enrichment and characterized by a high rate of organic production.

EUTROPHICATION : The process of becoming increasingly enriched in nutrients. It refers to the entire complex of changes which accompanies increasing nutrient enrichment. The result is the increased production of dense biological growths such as algae and aquatic weeds which generally degrade water quality and render the lake unsuitable for many recreational activities.

FECAL COLIFORMS (FC) : Fecal coliforms are bacteria associated with recent fecal pollution from man and animals.

FECAL STREPTOCOCCUS (FS) : Fecal streptococcus are bacteria associated with fecal pollution from animals and to a lesser extent man.

HARDNESS : Hardness of water is a measure of the total concentration of calcium and magnesium ions expressed as if all of the ions were calcium carbonate.

HYPOLIMNION : The uniformly cold and deep layer of a lake lying below the thermocline, when the lake is thermally stratified. Diagram #1

KJELDAHL NITROGEN : Sum of nitrogen present in the ammonia and organic forms (it does not include nitrite or nitrate).

MESOTROPHIC : Waters characterized by a moderate nutrient supply and organic production (i.e. midway between eutrophic and oligotrophic).

METALIMNION : See thermocline.

OLIGOTROPHIC : Waters containing a small nutrient supply and consequently characterized by a low rate of organic production.

pH : Is the measure of the hydrogen ion concentration expressed as the negative logarithm of the molar concentration.

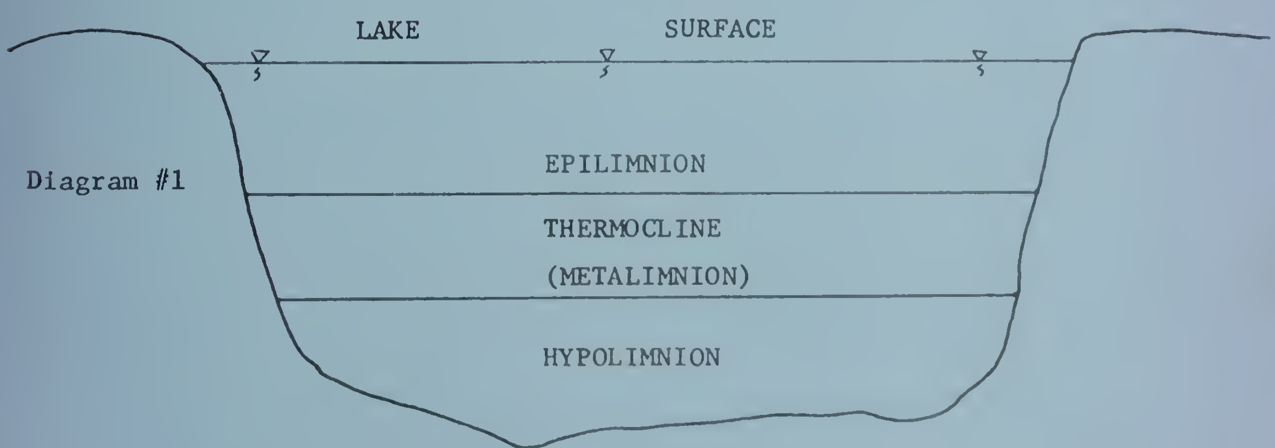
PHOSPHORUS (TOTAL) : Sum of all forms of phosphorus present in the sample.

SECCHI DISC :A circular metal plate, 20 centimeters in diameter, the upper surface of which is divided into four equal quadrants. Two quadrants directly opposite each other are painted black and the intervening ones white. The secchi disc is used to estimate the turbidity of the lake water.

THERMAL STRATIFICATION :During the spring, vertical temperatures in a lake are homogeneous from top to bottom. As summer advances, the surface waters become warmer and less dense than the underlying cooler waters. A strong thermal gradient (Thermocline) occurs giving rise to three distinct water layers. The variation in density between layers retards mixing by wind action and water currents. Diagram #1.

THERMOCLINE (metalimnion) :The layer of water located between the epilimnion and hypolimnion in which the temperature exhibits a decline equal to or exceeding $1^{o}C$ increase per meter.

Diagram #1



TOTAL COLIFORMS (TC) :Total coliforms are bacteria commonly associated with fecal pollution but may also be present naturally in the environment.

TROPHIC STATUS :Depending upon the degree of nutrient enrichment and resulting biological productivity, lakes are classified into three intergrading types:

TROPHIC STATUS (continued)

:oligotrophic, mesotrophic and eutrophic. If the supply of nutrients to an oligotrophic lake is progressively increased, the lake will become more mesotrophic in character and with continued enrichment it will become eutrophic.

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Microbiological Criteria

Water used for body contact recreational activities should be free from pathogens including any bacteria, fungi or viruses that may produce enteric disorders or eye, ear nose, throat and skin infections. Where ingestion is probable, recreational waters can be considered impaired when the coliform fecal coliform, and/or enterococcus geometric mean density exceeds 1000, 100 and/or 20 per 100 ml respectively, in a series of at least 10 samples per month, including samples collected during weekend periods.

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